Infrastructure outcomes: What the operational budgets of new projects tell us we are missing

Carron M Blom (MSc (Hons), FIPENZ, MRMLA, MRSNZ, MAMINZ), PhD Candidate, University of Cambridge. cmb216@cam.ac.uk (*corresponding author*)

Peter M Guthrie (OBE, FREng, FICE), Director of the Centre for Sustainable Development, Department of Engineering, University of Cambridge

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Abstract

This research responds to issues identified with the forecasting of operational expenditure by providing an in-depth analysis of a multi-modal transportation programme from New Zealand. It shows material issues that are likely to be of relevance to wider infrastructure practice. It also indicates that management tools and processes can inadvertently result in budgetary and operational omissions. Significantly, those omissions include the very service, societal, and environmental requirements upon which the programme was predicated, and also omitted provisions for the long-term maintenance of major assets (such as bridges and other structures). A more holistic model is therefore proposed to support a re-orienting of practice towards an integrated whole-of-system approach.

Introduction

Auckland is New Zealand's largest city of approximately 1.4 million people (Statistics New Zealand, 2013). Seven local councils within the 4,938km^2 region were recently amalgamated with regional government to form a 'super city' ("Local Government (Auckland Council) Act," 2009). Several Council Controlled Organisations were also established at that time, including Auckland Transport, which as its names suggests, is responsible for transportation management in the region (excepting the State highway network), and is the subsequent focus of this paper.

This paper is presented in New Zealand dollars, since those are the units of the source material. At the time of writing, NZD$1 equalled approximately USD$0.73 or GBP£0.55.

Auckland Transport's strategic documents identify an estimated NZ$60 billion of capital investment over the next three decades (Auckland Transport, 2013a, p. 1); with the short term annual capital works budget between approximately NZ$600 and NZ$650 million excluding renewals (Auckland Transport, 2014b, p. 26). NZ$1.86 billion over the next 10 years has been provided for "*network maintenance and asset operations*". In this context, this means the maintenance of the local road network, and transport-related assets such as public transport facilities and commuter rail depots and rolling stock, but excludes the provision of transportation services, or maintenance of the wider rail and State highway networks. Notwithstanding any limitations with the current approach to estimating operational expenditure (OPEX), this excludes growth, the current renewals programme, and the "*increased requirement for maintenance that will arise from the reduced level of renewal investment from 2019 onwards*" (Auckland Transport, 2015b). Auckland Transport estimates the additional 1.5% of asset growth will result in an annual increase in operating expenditure (or 'consequential OPEX') of some NZ$2 million, bringing the total OPEX to NZ$119 million over a ten year period — just to stay apace of the growth in assets (Auckland Transport, 2015b). Yet (emphasis added):

> *"Historically, there has been little, if any, coupling between the capital development programme and the increases to maintenance and operational costs.* [Capital expenditure (CAPEX)] *and* [Operational Expenditure (OPEX)] *budgets are mainly viewed and managed in isolation.* ***There is little visibility or reporting around the consequential OPEX implications of capital development at a board or executive leadership level.***
>
> *Whilst operational budgets have been increased to allow for growth, this has largely been on the basis of a simple percentage uplift. Historically this has been in the range 0.8% to 2.5%* [of the existing operational budget]*, with the level mainly influenced by budget pressures or linked to population increase.*
>
> *This formulaic approach does not accurately reflect the increasing pressure on operational and maintenance budgets arising from:*
>
> 1. *The growing influence of amenity and urban design considerations in infrastructure design*
> 2. *The increasing use of non-standard materials and fittings*
> 3. *Increasing network complexity and interrelationships."* (Auckland Transport, 2014a)

Not surprisingly, Auckland Council (Auckland Transport's sole shareholder) also considers the impact of 'consequential OPEX' to be a key issue at this time (Auckland Council, 2012). And Auckland is not alone. As part of a review of all New Zealand local authorities' audited financial statements and the long-term plans and asset management information for 31 local authorities, the Controller and Auditor-General (2014a), found that:

> *"When local authorities forecast their spending, they typically base their forecasts on assumptions about …* [amongst other things, the] *consequential effects on operating expenditure of the forecast capital additions".*

There is, however, a perception by some that consequential OPEX is minor, and so does not warrant detailed evaluation; in considering the drivers of local government expenditure in New Zealand, GHD (2007) was of the view that:

> *"One would expect that for transport, capex has a small influence on opex because usually a capex project is a relatively small part of an extensive transport network and opex costs occur 10-15 years later – apart from debt servicing".*

Yet such issues are not limited to the New Zealand local government or transportation sectors. For example, Blom and Guthrie (2016) found the underlying operational system rarely adjusts to accommodate changes arising from the delivery of a new project (e.g. changes to maintenance or other specifications/contracts and/or delivery of additional projects or changes to assets or services).

The Green Book (HM Treasury, 2011) also observes that:

> *"Many project parameters are affected by optimism – appraisers tend to overstate benefits, and understate timings and costs, both capital and operational."*

However, optimism bias (as it is known) is a slightly different matter from the focus here, as it relates to project and investment decision-making in the first instance. The cited incidence of OPEX underestimating (HM Treasury, 2011)), coupled with the use of consequential OPEX forecasts (Controller and Auditor-General, 2014a), suggests that the handover of operational schedules prepared during the project delivery stage is not occurring and/or these are not being used by, or have relevance to, the operational division(s) of an infrastructure organisation.

This research responds to this problem by providing an in-depth analysis of the 'consequential OPEX' of a complex, multi-modal transportation programme from New Zealand. Rather than the usual project or asset management approaches, the research instead adopts a whole-of-organisation, and system-oriented perspective. Interviews spanning multiple infrastructure sectors and countries were also used to augment the research and test its broader applicability. The focus of the case study is how OPEX arising from new project CAPEX has been estimated by the operational divisions of an infrastructure provider, and the implications this has for long-term infrastructure outcomes.

Definitions and current conventions

OPEX is typically defined as, and understood to be, operational expenditure/operations expenses (e.g. Audit New Zealand, 2010; Greffioz, Olver, & Schirmer, 1993; Lantz, 2013; Van Themsche, 2016). Simply put, it includes all costs required to provide services (e.g. public transport), and to operate and maintain assets at defined levels of service over the long term at an asset, network, and systems level. Also included are "*costs for operations personnel, materials, fuel, chemicals and energy consumption*" (National Asset Management Support (NAMS) cited in Audit New Zealand, 2010). Some costs may derive from new capital expenditure (CAPEX), and this has been termed 'consequential OPEX' to reflect current industry use (e.g. Auckland Council, 2012; Auckland Transport, 2014a; and to paraphrase, Controller and Auditor-General, 2014a). The term has been adopted by infrastructure practitioners as a shorthand way of defining new project operational costs as a subset of the wider OPEX budget, and to distinguish the estimate from any of those prepared as part of project development or delivery.

With such an all-encompassing but clear definition, it might be supposed that understanding OPEX, and more so consequential OPEX, is relatively straightforward. Unfortunately this does not appear to be supported by either literature or industry practice. Indeed the literature is rather sparse in advancing matters much beyond the generic definition. However:

- Greffioz et al. (1993) identify three commonly used methods for assessing OPEX for oil and gas production facilities: the use of multiplication factors applied to CAPEX, the use of spreadsheets, and "*ad hoc comparisons with previously estimated or known costs for other similar plants*".
- HM Treasury (2011) states that:

  "Sensitivity analysis should be used to test assumptions about operating costs and expected benefits.

  Adjustments should be empirically based, (e.g. using data from past projects or similar projects elsewhere), and adjusted for the unique characteristics of the project in hand. Cross-departmental guidance for generic project categories is available, and should be used in the absence of more specific evidence. But if departments or agencies have a more robust evidence base for cost overruns and other instances of bias, this evidence should be used in preference. When such information is not available, departments are encouraged to collect data to inform their estimates of optimism, and in the meantime use the available data that best fits the case in hand."

Asset management practice also includes consideration of operational cost as the following definitions demonstrate (NAMS, 2011):

- Asset management: *"The systematic and coordinated activities and practices of an organisation to optimally and sustainably deliver on its objectives through the cost-effective lifecycle management of assets."*
- Lifecycle cost: *"The total cost of an asset throughout its life including planning, design, construction, acquisition, operation, maintenance, rehabilitation and disposal costs."*

ISO (2014a, 2014b) is less specific, with 'lifecycle' being simply the "*stages involved in the management of an asset*", and noting that "*the naming and number of stages and the activities under each stage usually varies in different industry sectors and are determined by the organisation*". However, similar definitions to those used by NAMS may be found in other asset management guidance (e.g. The Institute of Asset Management, 2008).

Some might perceive asset management to therefore be sufficient (see also Blom & Guthrie, 2016). However, there are a number of issues with such an assumption:

- OPEX is not limited to physical infrastructure and assets; and
- Asset management processes and tools:
  - Often have gaps in data capture and other reliability issues (Controller and Auditor-General, 2014b, p. 30; GHD, 2015);
  - May have been developed for linear assets (such as those within a road corridor), so may not be suitable for non-linear and/or complex assets such as public transport facilities, parking, town centres, and 'blue-green' infrastructure such as wetland ponds and rain gardens (e.g. Blom, Irwin, & Rangamuwa, 2011);

Furthermore, areas of asset management practice should not be confused with the ability (or need) to develop an appropriate operational budget. Or, as noted, be misconstrued as necessarily providing for all organisational needs.

Projects delivered by Auckland Transport (the subject of this study), are partially funded through a land transport fund administered by the New Zealand Transport Agency (NZTA). As a consequence, NZTA funding requirements and guidance documents are relevant to, and have an influence on current practice (e.g. NZTA, 2010; NZTA, 2013a, 2013b). Unfortunately, any discussion of whole-of-life costs and consequential OPEX is also limited, and may in fact result in perverse outcomes in some instances. For example the NZTA cost estimation manual (NZTA, 2010), defines 'whole of life' as the period from project investigation and reporting through to the end of construction (and such an assessment was undertaken for the case study discussed later). This is not necessarily inconsistent with wider practice. ISO (2011), for example, describes lifecycle costing as a "*methodology for systematic economic evaluation of life-cycle costs over a period of analysis, **as defined in the agreed scope***" (emphasis added).

So whilst there may be a perception that consequential OPEX is, or should also be covered within a whole-of-life assessment, as this shows, a lifecycle assessment does not necessarily provide for everything. There is therefore a good possibility that there will be miscommunication around the term 'whole-of-life' assessment, with the meaning 'lost in translation'.

Where a whole-of-life assessment is undertaken as part of a project business case or investment decision, any sensitivity analysis and/or long-term implications may also be obscured by the use of discount factors. Yet from an operator's perspective, discount factors do not apply — indeed OPEX figures need to be inflation adjusted. As long-term expenditure is not static and needs to respond and adapt to an evolving asset condition, levels of service, and context, there is a need to address consequential OPEX for operational needs. This requires a whole-of-organisation, and a system-oriented approach.

Whilst Dobbs et al. (2013, p. 7) have observed that there are significant opportunities to optimise infrastructure maintenance and operational practice, they do note that the first step in this is to assess and catalogue needs. The New Zealand Controller and Auditor-General (2014b, p. 6) appears to concur:

> *"Spending according to budget is only sensible and appropriate if the budget is likely to be a good guide of what should be spent".*

Such a basic and perhaps obvious step of firstly understanding what is required appears not to have received the attention it should. After all, "*if you rely on something, you need to recognise it and manage it over the long term*" (Controller and Auditor-General, 2014b).

Case study overview

This research is part of a wider programme which investigates the relationship between the strategic intent and management of infrastructure systems. Consideration was therefore given to the selection of both the transportation sector and the New Zealand context; this is described within Blom and Guthrie (2016). As part of the initial framing of the overarching research, practitioners from a range of infrastructure sectors and countries were asked whether competence was a factor; as it would be easy to summarily dismiss issues such as those identified here for this reason. However, Blom and Guthrie (2016) found that it was not so simple.

So for completeness and context, we note that although a New Zealand case study has been selected to research this issue, New Zealand has had a strong reputation in public sector reform (Hood & Peters, 2004, p. 286; Sehested, 2002, p. 1523; The World Bank, 1998, pp. 80-82, 155), and thence Asset Management, particularly in road infrastructure (Aikman & Doherty, 2006, pp. 4157-4158; Federal Highways Administration, 2005; and NAMS, 2011 (which is referenced in the ISO 55000 series, 2014)). Preceding amalgamation, local government in the Auckland region had also previously contributed examples of good asset management practice to industry guidance (e.g. Audit New Zealand, 2010).

Project description

The Auckland-Manukau Eastern Transport Initiative (AMETI) is a major, multi-modal programme aimed at improving strategic transport links in the east of Auckland, and comprises:

> *"An integrated package of improvements to all transport modes in the Panmure area, designed to improve the transport choices so as to reduce dependence on private car use and facilitate land use changes to improve the area economically, socially and environmentally."* (Auckland Transport, 2013b, p. 48)

The programme is divided into several stages. The first of which (and the focus of this case study), was completed in 2014 (Figure 1). The main components of Stage 1 (or 'the project') include (Auckland Transport, 2013b, pp. 48-49):

- The reconstruction of two road bridges and one footbridge;
- Construction of a covered box structure (accommodating the rail station and link road), plus an additional pedestrian / service vehicle bridge;
- A local road realignment;
- Construction of a new link road (Te Horeta Road);
- Upgrades to an existing rail station, creation of a new rail / bus interchange, and the addition of new bus lanes;
- Improvements to walking and cycling facilities;
- Establishment of public open spaces, park and ride facilities, and environmental mitigation works including noise wall construction, improvements to coastal outfalls, stream 'daylighting', and the rehabilitation of a wetland lagoon (integrated with stormwater management).

At the time this research programme commenced, AMETI was the largest programme under construction for Auckland Transport and one of the largest transportation projects of the region.

The overall (uninflated) programme capital expenditure (CAPEX) estimate is NZ$1.16 billion, and the Stage 1 outturn cost was approximately NZ$215 million (Auckland Transport). The Stage 1 OPEX is assessed within the case study detail to follow.

Current Auckland Transport practice

Auckland Transport has advised that consequential OPEX is currently assessed at the 'programme' level rather than on an individual project basis, as follows (Auckland Transport, 2014a):

1. *"Identify the individual asset classes created by each project included in the capital new work programme.*
2. *Establish the level of growth (the increase in the quantity of the asset) for each asset class using a representative sample of projects.*
3. *Assess the annual increase for each asset class using the ratio of the value of the new assets being created to the aggregated replacement value for that asset class.*
4. *Apply the ratio calculated to the operational budget for that asset class."*

The organisation is aware of the shortcomings of this approach, and is working on the development of a more robust method. This study is understood to be informing that process, so provides an example of the application of systems thinking to action research (Flood, 2010).

Compliance context

In Campbell, Jardine, and McGlynn (2011), legal compliance and the environment are two of five identified 'hidden' operational costs. However this misses the point: legal compliance is mandatory. Costs should therefore be identifiable by association with known actions and requirements.

Notably, in New Zealand, the Resource Management Act (RMA; 1991), provides the framework for the sustainable management of natural and physical resources. The Act includes criminal liabilities and significant fines for offences against the Act (s.339), underlining both the compulsion and the significance of understanding and implementing compliance requirements. AMETI required several authorisations under the RMA, which have conditions to avoid, remedy, or mitigate adverse effects, and which include long-term requirements.

Methodology

As noted, the impetus for this study derives from a wider research programme. The first phase (problem definition) identified the project: operational interface as one of three key areas for further investigation (Blom & Guthrie, 2016). Consequential OPEX was identified as a useful means of exploring this and has been able to use the earlier research to test and augment this case study; the methodology for which is described by Figure 2.

The main task comprised the review of some 128 detailed project documents to enable the development of a consequential OPEX schedule from first principles, but with reference to existing contracts and the organisation's Asset Management Plan (Auckland Transport, 2015b). Where costs were available from previous estimates, these were added to the schedule. The schedule was then provided to Auckland Transport to cost, and compared with other recent estimates of OPEX as well as a high-level comparison with other projects.

Although multiple parts of the organisation were involved, the schedule could only be partially populated. Some costs, such as road markings, could be estimated to the nearest dollar, whereas the costs for areas such as compliance and structures were largely absent. The organisation concluded it would need to outsource the estimating to complete the schedule. In short, basic operational requirements were not readily available or understood, and this was affecting the scope of ongoing operational actions.

As the consequential OPEX schedule was compiled, key issues to emerge from the project documentation were also noted and assessed. The process was augmented by information derived from a cross-section of other transportation projects within the region as well as from a series of industry interviews:

- 40 semi-structured infrastructure industry interviews in New Zealand and within the European Union, plus a further 19 general interviews within Auckland Transport as the case study organisation. These were undertaken as part of the problem definition phase of a wider research programme, of which this study forms a part (see Blom & Guthrie, 2016).
- An additional 6 semi-structured interviews with staff from across Auckland Transport, including the Programme Director, as well as senior consultant advisors. These were to source and clarify information, and to seek views on preliminary observations.

Whilst the requirements and merits of case study research have been argued by Eisenhardt (1989), Flyvbjerg (2006), and Yin (2003), the choice of the AMETI case study was also considered appropriate in this instance for the following reasons:

- The methodology investigates consequential OPEX from across the infrastructure lifecycle and across the study organisation. This might therefore be viewed as a series of studies that look at a single project through different perspectives.
- The study organisation reflects the immediate past of multiple organisations. Using a recently amalgamated organisation not only effectively collates best practice; it should reduce the likelihood of defensive or blaming behaviours as staff may not have so much 'ownership' of past processes and projects. The study organisation was also actively seeking to improve its practice in this area.
- The assessment was able to be augmented and tested by previous industry wide research; providing a degree of triangulation.
- The project:
    - Includes provisions for rail, bus, walking and cycling, freight and over-dimension (size/weight) vehicles, plus general traffic. The scope includes significant structures (including a tunnel), public transport facilities as well as transport networks, and significant environmental and cultural issues. It is therefore complex enough to enable a range of pan-organisational issues to be canvassed (i.e. that might not arise from a straight forward road widening); yet
    - Is deemed (by Auckland Transport) to be sufficiently representative of wider practice;
    - Is of sufficient magnitude (size and cost) to attract and/or demand proponents of best practice within both the study organisation and the wider New Zealand transportation sector.
    - Enables extrapolation across multiple programme stages all of which are based on that of Stage 1.

The local government reforms in this region, together with the selection of a project that was instigated pre-amalgamation, also provided an opportunity to explore processes without a high degree of lock in.

For completeness it is noted that whilst operational revenues are important, the focus of this research is upon expenditure from the perspective of the day-to-day organisational operations. The study therefore does not revisit the whole-of-life assessment or the benefit: cost ratio calculated as part of the initial programme investment decision-making. Similarly, whilst various procurement options may purport to offer different operational outcomes; there is still a need to investigate this area — at least within the New Zealand setting — where infrastructure is largely in public ownership, and public-private-partnerships used selectively.

Assessment of Consequential OPEX

The revised schedule of consequential OPEX theoretically enabled the reassessed costs (termed the 'amended consequential OPEX') to be compared with several other estimating methods (Table 1). These cover the generic methods outlined by Greffioz et al. (1993) and HM Treasury (2011) as described previously. Indeed, the amended consequential OPEX schedule identified wide range of matters that other estimating techniques had failed to identify. However, only some of these were able to have costs determined. Accordingly, the amended consequential OPEX figures still exclude a significant number of cost items that were also missing from other estimates, such as (but not limited to):

- The cost of completing the project or rectifying issues (e.g. completion of stormwater treatment and related amenity requirements). These are considered to be CAPEX but remain outstanding costs to the organisation.
- The incremental cost to general overheads (i.e. if the project requires less than one full time equivalent for any one role). These were seen as the 'cost of doing business' but included a substantial scope and list of un-costed activities / resource requirements.
- Variations to existing maintenance / operational contracts: these would not be 'seen' within the estimate until retendering of the associated contract.
- Longer term costs, particularly assets such as significant structures that have increased maintenance requirements and costs towards the end of their design life. There is no current framework for estimating these and then accounting for the costs that will eventually be incurred, but which is currently outside the budgetary cycle of 3 years or the long-term estimating period of 30 years.
- Costs that are too difficult to readily break down to the project level (e.g. finance, insurance) or to cost (e.g. the cost of changing context or technology, natural disasters, risk). These include costs that could not be assessed as requirements could not be identified (e.g. because some of the required management plans have not been delivered), together with ongoing programmes to help the system evolve (such as network optimisation).

It is important to note that this exercise has not added new requirements. Rather it captured undertakings made within design reports or required within consent and other approvals related documents and authorisations; all of which would have been subject to sign off as part of project development and delivery. However these can be 'lost to the system' when project records are archived at the end of the project delivery phase.

This is an important point, as comparison of schedule scope, let alone the costs, highlights a significant number of requirements for which costs have not been previously assessed. Indeed operational personnel indicate that they were not even aware of many of the ongoing requirements. Although not the sole reason, there is a danger that without budgetary prompting, operational requirements get overlooked. Ackoff (2006) offers an apposite observation in this regard:

> *"Accounting systems in the western world only take account of errors of commission, the less important of the two types of error. They take no account of errors of omission. Therefore, an organization that frowns on mistakes and in which only errors of commission are identified, a manager only has to be concerned about doing something that should not have been done. Because errors of omission are not recorded they often go unacknowledged. If acknowledged, accountability for them is seldom made explicit. In such a situation a manager who wants to invoke as little disapproval as possible must try to either minimize errors of omission or transfer to others responsibility for those he or she makes."*

The implications of course go beyond simple accounting practice, as this affects what 'gets done' and in the case of compliance or social and environmental outcomes, what costs (and/or effects) are ultimately externalised. Flyvbjerg, Holm, and Buhl (2002) also touch on this point, but in relation to project delivery:

> *"Project promoters and forecasters may deliberately underestimate costs in order to provide public officials with an incentive to cut costs and thereby to save the public's money. According to this type of explanation, higher cost estimates would be an incentive for wasteful contractors to spend more of the taxpayer's money. Empirical studies have identified promoters and forecasters who say they underestimate costs in this manner and with this purpose, i.e., in order to save public money (Wachs, 1990)."*

The effect of such practice is to disincentivise the inclusion or consideration of consequential OPEX early within project delivery process lest this affect the business case. The absence of feedback within the process (Flyvbjerg, Skamris Holm, & Buhl, 2003) is such that project managers are unlikely, in any event, to be held to account for any OPEX estimated during this phase.

This exercise has shown significant adjustments need to be made to consequential OPEX estimating practice, and that OPEX:CAPEX ratios can be misleading. However whilst the percentage change is significant, an annual increase of $1.23M over previous estimates (or even $6.23M with the new public transport services included) may not be seen as significant when considered in the context of the operating budget as a whole (approximately $186 million annually). The 'known' or 'identifiable' impact of the first stage of AMETI alone, with a CAPEX of NZ$215 million is approximately 5% inclusive of public transport services, or if these are still to be reported in a separate budget, then by approximately 1%.

However the total AMETI programme has an estimated CAPEX of NZ$1.16 billion. Setting aside the additional public transport services for the time being, if the same issues are replicated across the remainder of the AMETI programme (which is reasonable to expect), this will have an impact on the Auckland Transport's OPEX budgets by approximately 5% (even with the extensive estimating limitations). However if just the Stage 1 'additional costs' (see Table 1) are added to an amended consequential OPEX figure for the whole AMETI programme, the impact on the overall annual organisational OPEX is approximately 10%, and challenges the assumption that CAPEX does not significantly affect OPEX in transportation (GHD, 2007). There is then an obvious question as to whether similar ‘discrepancies’ exist across the organisation and other projects or programmes. The organisation itself considers the AMETI to be an indicative programme and of a scale to test a large number of organisational processes and practice.

Another counterpoint to the possible perception this might be an inconsequential ‘error’ is that the cost of actually completing all of the tasks originally proposed, thereby enabling the delivery of the envisaged project benefits (compliance, sound engineering, function / social / system outcome, reputation) – is relatively small. The additional CAPEX to address system shortfalls by contrast is somewhat more significant and therefore presents an opportunity cost to the organisation. The impact of opportunity cost, such as other projects not being delivered or reduced levels of service, has not specifically been assessed through this exercise and remains an area for further study.

Wider implications

The reassessment of the consequential OPEX estimate should enable improvements to the estimating process, by identifying firstly a need to look in further detail and secondly, some of the key areas requiring further attention. This is what Argyris and Schön refer to as single loop learning (cited in Pahl-Wostl, Holtz, Kastens, & Knieper, 2010). Yet the very process of developing and estimating the schedule has highlighted a different set of interrelated issues that underline the importance of looking across the infrastructure lifecycle, the wider system, and organisation. In many ways, these are equally, if not more important than the ‘bottom line’ as they are not only likely to influence the estimate but help to identify areas where attention is needed to affect systemic change.

Consideration of these issues, which have been summarised in Table 2 for necessary brevity, provides a further learning opportunity in which existing assumptions can be revisited within their existing organisational frameworks. Argyris and Schön refer to this as ‘double loop learning’ (cited in Pahl-Wostl et al., 2010).

Discussion

Bosch, Nguyen, Maeno, and Yasui (2013, p. 118) use an iceberg analogy to describe the management of complex issues. They argue that the obvious symptoms or quick fixes are only a very small part of the approach required and rarely offer long-term solutions. Instead, they suggest a further three levels of thinking which “*hardly ever comes to the surface*” (Bosch et al., 2013, p. 117). Interestingly, these aligned with three of the key points that warrant further discussion around this matter of consequential OPEX:

- Change management (including interactions between components);
- Controlling (mental) models; and
- System structure.

One further matter relates to the implications of this research for infrastructure governance and high-level decision making. Governance in this context relates to the board level rather than political function.

Change management

To again cite Bosch et al. (2013, p. 116), complex issues are unlikely to be resolved with linear thinking or single solution, which can be challenging for a technically based organisation. Although the matter of consequential OPEX might be viewed as simply a combination of the project to operations handover and thence the reliability of the estimate, the range of wider issues (Table 2) demonstrate the reality is much more complex. Figure 3 presents those same issues graphically, showing a preliminary assessment of the linkages and connectivity between the various factors. Whilst the handover and estimating processes might be a good place to start, attention will need to be given to the wider system if change is to be both effectual and enduring.

There is of course a second dimension to the matter of change management in this context; it is one thing to change the existing system, it is quite another to respond to the dynamic nature of (or change to) that system. This is where the conventional linear representation of the infrastructure lifecycle is singularly unhelpful (Figure 4). Whilst there may be a view that projects have a life of their own (Flyvbjerg, 2009; Flyvbjerg, Bruzelius, & Rothengatter, 2003), ultimately projects should respond to an operational need, which is in turn providing a societal outcome. A systems lifecycle such as that proposed by Blom (2014) is perhaps more helpful in this regard (Figure 5). The current penchant for 'best for project' also needs to urgently be refocussed at the system level and ultimately the end user or community.

Whilst the wider issues of the existing system will be a good guide for managing the transition of projects back into the operational system, this will need to be periodically reviewed (we turn to this next). Goodman and Ramanujam (2012, p. 6) have identified three matters which they suggest need to be addressed if change is to be effectual at the organisational level: people, organisational structure, and technology (taken to also mean technical change in this context). A change matrix results if these are combined with the central themes identified by this research (Table 3).

Goodman and Ramanujam (2012) caution that negative change "*can result in an unintended, and often unacknowledged, risk: a buildup of latent errors in operations.* [Managers] *must consider ways to enhance organizational attention and memory during and after the implementation of major change…*". We would concur, but given Goodman and Ramanujam use Dekker's definition of latent errors ("*deviations from rules and standard operating procedures that can potentially result in adverse outcomes of organizational significance*"(Dekker in Goodman and Ramanujam (2012))), we are of the opinion that this does not go far enough. Rather, this research has indicated a need for there to be a continual review of processes and procedures. We argue next that sometimes this needs to be more than incremental change.

The overarching point here is that the transfer of a project into the 'system' creates 'threads' of action and change that need to be followed through that system, and there needs to be accountability for doing so. The corollary is that all dimensions and all of the key issues within the matrix need to be addressed to reduce the likelihood of similar problems being encountered in the future. Ongoing change, and change management will be important in an evolving system, modified by project delivery and changing context:

> "*It is important to note that reliable performance in complex systems is complicated because it is a dynamic, non-event that is difficult to specify and visualize. It is dynamic because safety is preserved by timely human adjustments; it is a non-event because successful outcomes rarely call attention to themselves. Because reliable outcomes are constant, there*

> *is nothing to pay attention to. This can decrease vigilance, the sense of vulnerability, increase the propensity towards complacency and inertia and decrease the quality of attention across the organisation. This can be deadly. Although adverse outcomes, sometimes, occur because of performance and execution mistakes, there are flaws in that portrayal. Mistakes in perception, conception and understanding lead to much greater harm.*" Sutcliffe (2011)

Controlling models

It is clear that multiple departments and disciplines need to contribute to the assessment of consequential OPEX. Moreover, any approach needs to be more than the summing of parts to provide a whole-of-organisation, whole-of-life cost. Both Bosch et al. (2013); and Newell et al. (2005) observe the importance of mental or controlling models when integrating different functions, departments, or disciplines. There are two areas where this research suggests that convention, and therefore the associated controlling (mental) models merit a review.

Albeit that this is starting to change, the first relates to the prevalence of the project oriented mind-set, organisational structures, and general industry practice prevalent not only within the study organisation, but within the wider infrastructure industry. This has already been touched upon (see also Blom (2014); and Blom and Irwin (2011)). However this is considered to be crucial for effecting change going forward.

The second relates to historic context. The current practice that surrounds project delivery and the estimation of consequential OPEX draws upon industry convention and organisational learning; in other words 'history'. In this instance Auckland Transport has had the opportunity to draw upon best practice from its 'legacy' council organisations. This can result in incremental change which is, in many respects, a form of institutional lock-in as it gives the impression of change but does not fundamentally reflect on the underlying mental models. This in turn may give rise to a sense of stability; something Snowden and Sutcliffe tell us is problematic (Snowden, 2003, 2005; Sutcliffe, 2011). The longevity of infrastructure will only serve to exacerbate this sense of stability.

During the course of this research, several points emerged which suggest it is timely to review how not only the matter of consequential OPEX is approached, but the overall management of infrastructure:

- Relevant information and costs were readily available for simple road-related assets, but significantly curtailed for complex or non-standard assets;
- Much of Auckland Transport's forward development programme and its overarching strategic objectives relate to transformation (Auckland Transport, 2013a, 2014b). Most of the significant projects (and therefore expenditure) relate to complex (technical, environmental or other contextual matters) and/or multi-modal projects, many of which interface with other organisations.
- Whilst the widespread use of prorated estimates might have been considered by infrastructure organisations to be appropriate, this was based upon considerable lengths of reasonably uniform road corridor, so variance was more likely to be absorbed within the averaging effect of that network.

- By contrast, there is not the same quantum for emerging complex assets, and therefore the ability to both schedule and cost in a way that adequately reflects the complexity of the asset is much more important than before.

Whilst obviously an issue for the matter of consequential OPEX (i.e. cost and performance information for novel assets need to be gathered then used), this also raises the bigger question of whether current approaches to infrastructure management are still relevant and appropriate. New Zealand, like many ‘new world’ or post World War countries, has undergone some 150 years of infrastructure growth. Although this continues, the nature of that growth has changed. Within Auckland’s transport context, the focus has shifted from simply infrastructure delivery (as a series of projects) to ‘transformational shifts’ notably: “*Move to outstanding public transport within* ***one network***” (emphasis added; Auckland Transport, 2014b, p. 6). The above points, visible at the consequential OPEX level, may well have the potential to inhibit Auckland Transport’s ability to meet its long-term objectives and strategies. Changing the controlling models, or the way in which infrastructure is viewed within the organisation as a whole, will therefore be an important part of an organisation’s ability to change, adapt, and learn. It would be expected that Auckland would not be alone in facing this issue (Blom & Guthrie, 2016).

System structure

Although the definition of OPEX is very simple and all encompassing, it was apparent from this research that at a practical level, it is not managed as such; accountability for a figure rests with one part of the organisation, but this does not include other contributing costs such as from public transport services. However, even if collated, this is still the sum of parts, and appears to be driven from functional reporting and data management tools rather than the actual overall costs. The research identified many underlying reasons for this but significantly, arising costs did not always neatly fit within currently defined budgetary categories and so were omitted. If this is not understood, like the example of ‘whole-of-life’ costing, this will be lost in translation, and there will be an expectation that OPEX figures are a holistic and all-encompassing assessment of ongoing operational costs.

Currently, and in simple terms, CAPEX consists of new project expenditure and asset renewals, and OPEX covers maintenance, services, and asset management. Maintenance and renewals are a sliding scale, so the threshold above which works are classified as OPEX or CAPEX may vary over time or from organisation to organisation. The interplay between maintenance and renewals is in itself significant as:

> “*Local authorities adopted financial strategies that included “just-in-time” responses to growth-related capital expenditure. Many reduced the forecast level of renewals and took a “sweating the assets” approach … and adopting “run to failure” approaches – which meant waiting until a component stopped working before replacing it, rather than replacing a component before it failed*”. (Controller and Auditor-General, 2014b, p. 14)

This has implications for how long-term maintenance and the associated budgets might be perceived and we return to this later.

Aside from the completeness of the OPEX estimate itself, there were two particular areas where costs were being omitted from the wider organisational system, both of which require a different means of managing funds than the current approach:

- CAPEX related deferred benefits: These are the 'claimed' project benefits that are not delivered due to scoping, specification, lack of follow through, budgetary constraints, or other reasons. Many relate to connectivity to a wider network such as those for bus priority, walking, and cycling.
- OPEX related adaptive capacity: This includes components that have the potential to arise over time such as emergency scenarios including natural disaster. However these are also as much about enabling the organisation to adapt and respond to change as they are to responding to risk. These include provision for technology or compliance requirements through review or renewal, future proofing, resilience related initiatives, and opportunistic works.

An associated matter is level of service, which relates to delivering the whole-of-life outcomes of the asset such as design life or services provided. Operational service levels can be affected by budgetary changes, or as seen through this research, get degraded through (for example) project decision-making, handover disconnects, or lack of specification. Instead it is suggested that operational levels of service should be fixed relative to how they were proposed (or at least provide a baseline for improvement over time). Any reduction should be related to need rather than budget boundaries acting as a proxy for such. This is also linked to the 'adaptive capacity budgets' for improvements to or reorientation of levels of service. Instead any discretion should rest within the CAPEX phase, how projects are specified, and in particular how investment is focused. This is aimed at supporting the current strategy of doing more with existing assets, and underlining the role of CAPEX in transforming the system.

Figure 6 proposes a new operational model to better provide for these factors. This not only provides a place for the more significant 'orphan' or currently hidden costs, but provides a tension between short- and long-term requirements. The approach also aims to increase transparency and certainty within the system.

The final point within this section is a challenge for those within finance (as this sits outside of the ambit of this research). The following issues were raised during this research, and it is clear that the current accounting approach is not well suited to long-term OPEX in the infrastructure sector, and needs to address a range of matters, including:

- Budgetary horizons: Long design-life infrastructure such as structures will likely have little routine maintenance within short to medium term budgets. These costs do however remain and will enter the 'system' at some stage. Currently these costs are being 'lost in time'.
- Discounting versus inflation adjustment: Linked to the preceding point, because initial whole-of-life costings are completed for funding purposes, discount rates are used (and exclude long-term maintenance requirements). By contrast, inflation is applied to any ongoing OPEX figure (but it appears long-term costs are omitted as these were not material when assessed initially). Early project and ongoing assessments of OPEX need to be undertaken from the organisation's operational perspective not just for funding purposes as they are asking and answering different questions.
- Non-conforming assets: Some assets, for example travel demand measures such as the 'walking school bus' (resource cost rather than a tangible asset), or appreciating assets such as riparian margins and wetlands may not sit neatly within standard accounting frameworks. Accounting imperative may therefore result in perverse outcomes or drivers in some instances.

- The use of time dependent (use it or lose it) budgets can be unhelpful in the operational preparation for project delivery (e.g. if project delayed), or in providing for the adaptive capacity of the system. Whilst there is a tension with rating practice and issues with the establishment of large contingency sums, this does not seem to be well provided for at present.

This is not to say that the system should be made unduly complicated, but rather some high-level changes are required to improve the system structure, and to provide better transparency and improved accountability for delivering strategic outcomes.

Governance

This research will also have implications for governance, in at least the following areas:

- OPEX specific: The true cost of OPEX, once known for the originally proposed levels of service, will have an influence on high-level strategies and decision making, and in particular the relative emphasis placed on maintenance, renewals, and long-term outcomes.
- More generally:
  - Well established management tools may promulgate a sense of certainty but may include significant levels of uncertainty and omission. The complexity of the contributing processes and organisational matters may make this difficult to 'unpick' when presented at a high level and may be masked by terminology, perspective, and expectation.
  - The dynamic and complex nature of infrastructure as a system requires change management and a periodic review of controlling mental models, both of which would benefit from governance leadership.

Conclusions

This research has provided useful insights at two levels. Firstly it has provided an in-depth study of how consequential OPEX is estimated and managed. This has highlighted a complex series of compounding issues that raise questions about veracity of consequential OPEX estimation and indicate that many factors are being lost in either translation or time. Eroded levels of services may not be immediately apparent as they may not manifest within the system in which it is managed (e.g. effects are externalised to the environment or society), or may not manifest within conventional business timeframes (e.g. effects or implications are not realised within 40 years). This, in turn, raises a second order of issues which relates to the impact this has upon long-term infrastructure outcomes. It corroborates earlier research which indicated that more attention needs to be given to the system perspective of infrastructure and the organisations that manage it. After all, this is "*arguably the level relevant to, and the reality of, much of the realm of day to day public infrastructure management*" (Blom & Guthrie, 2016).

Whilst the research has highlighted significant underestimation of consequential OPEX, the effect on the bottom line is only part of the equation. It is, perhaps, less relevant than what the study has shown about the wider issues within the technical-organisational realm and the context in which this sits. In the very least, the study qualifies the performance management maxim: you can't manage what you don't measure…and don't have a budget for. It is somewhat trite, but unfortunately necessary to add: but first you need to know what you are both required and intending to achieve.

There is considerable scope for additional research on this matter. Whilst this could include additional case studies, and/or other infrastructure sectors, there remain auxiliary questions such as what happens when assets are ‘vested’ to the public by a private developer, and whether alternative procurement, such as public/private partnerships necessarily address or defer the issues raised here. This paper also levels a challenge to those in finance to develop accounting practice that better facilitates and responds to the specific needs of public infrastructure governance and management. Finally, the research underlines the need to research the interface between engineering and management as it relates to infrastructure practice, but to do so with a focus upon long-term system outcomes.

Public infrastructure assets are a reflection of our development legacy, and of both past maintenance practice and budgetary factors. Cromwell (1991), for example, suggests that the dilapidated condition of infrastructure is not merely a reflection of the age of the existing capital stock, but rather an artefact of the compounding of project delivery oriented policy with bureaucratic and political pressures. With some US$57t of global infrastructure investment needed between 2013-2030 (Dobbs et al., 2013), understanding the long-term commitment to operational expenditure, and the actions and outcomes that underpin it, is paramount.

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Figures

Figure 1: AMETI staging plan

Source: Auckland Transport (2015a)

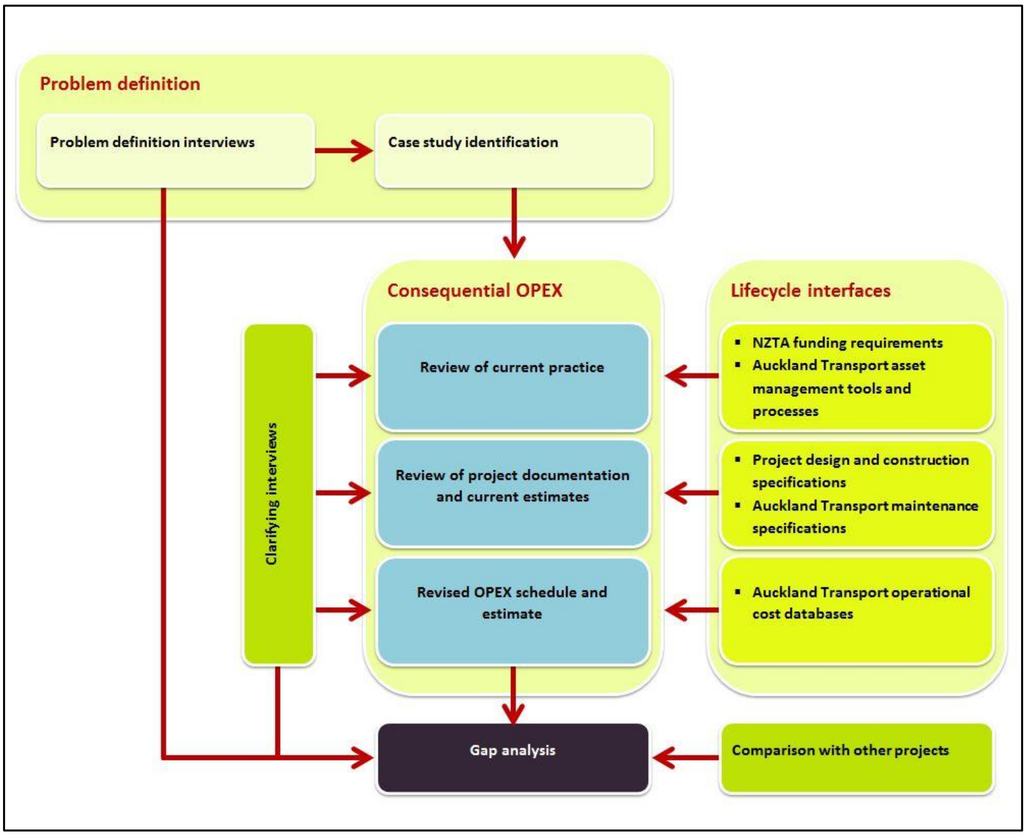

Figure 2: Methodology

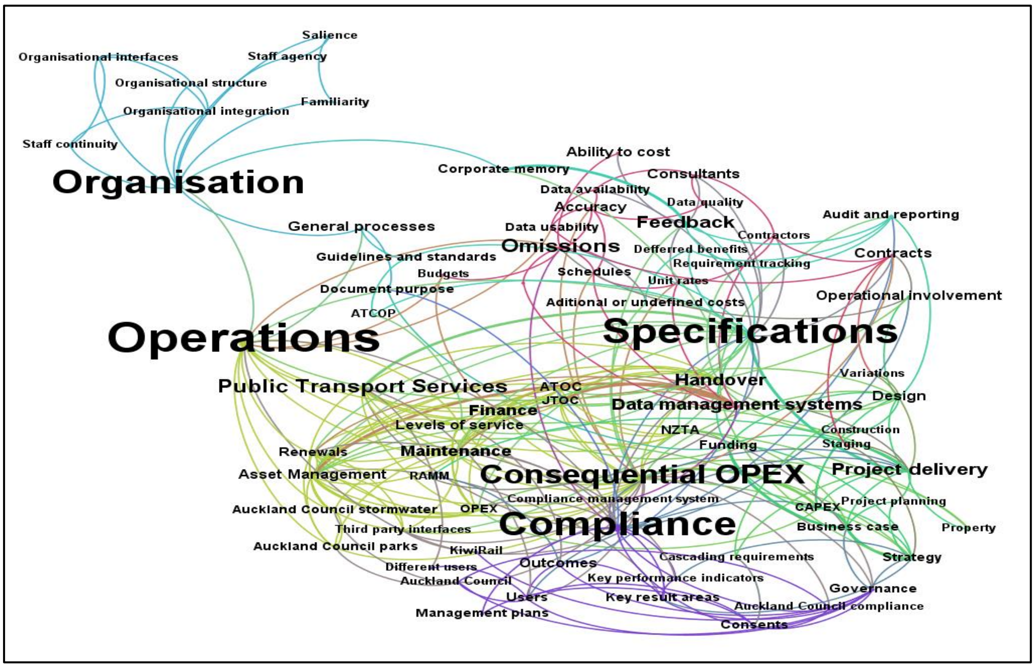

Figure 3: Preliminary mapping of issues surrounding the assessment of consequential OPEX

Project (acquisition) stage						Service (utilisation) stage	
Conceptual	Inherent	Strategy	Preliminary design	Detail design and development	Production and / or construction	Utilisation and support	Retirement and disposal

Figure 4: Conventional infrastructure life cycle

Source: Modified from Guthrie and Konaris (2012, p. 7); Lenferink, Tillema, and Arts (2008, p. 10); van der Lei, Herder, and Wijnia (2012, pp. 32-33)

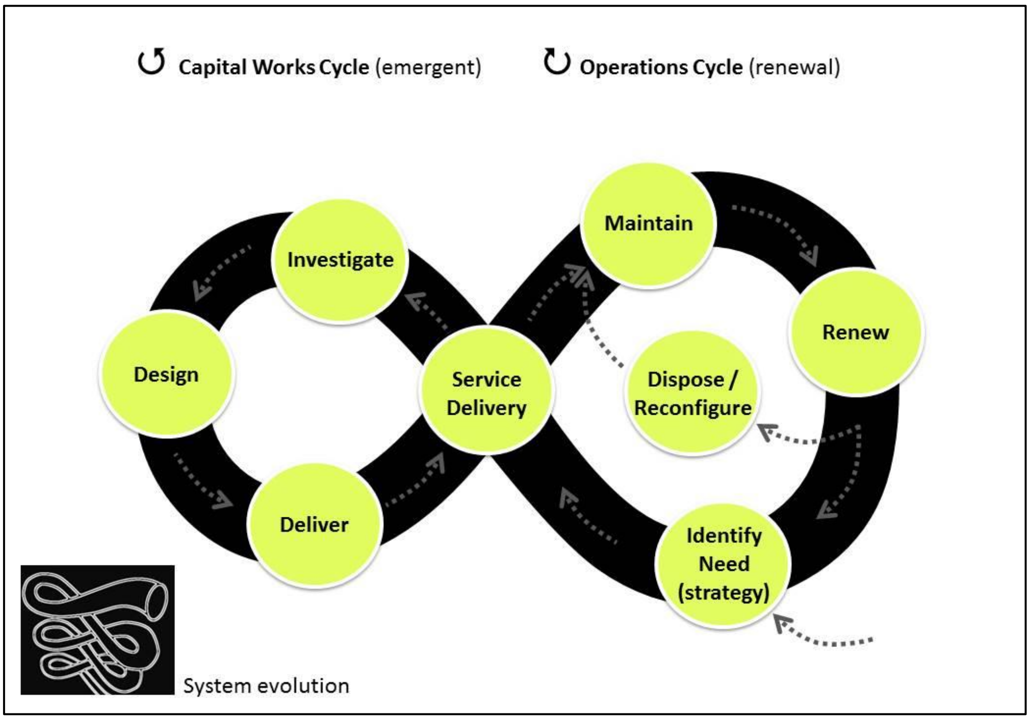

Figure 5: Infrastructure systems life cycle

Source: Modified from Blom (2014, p. 15)

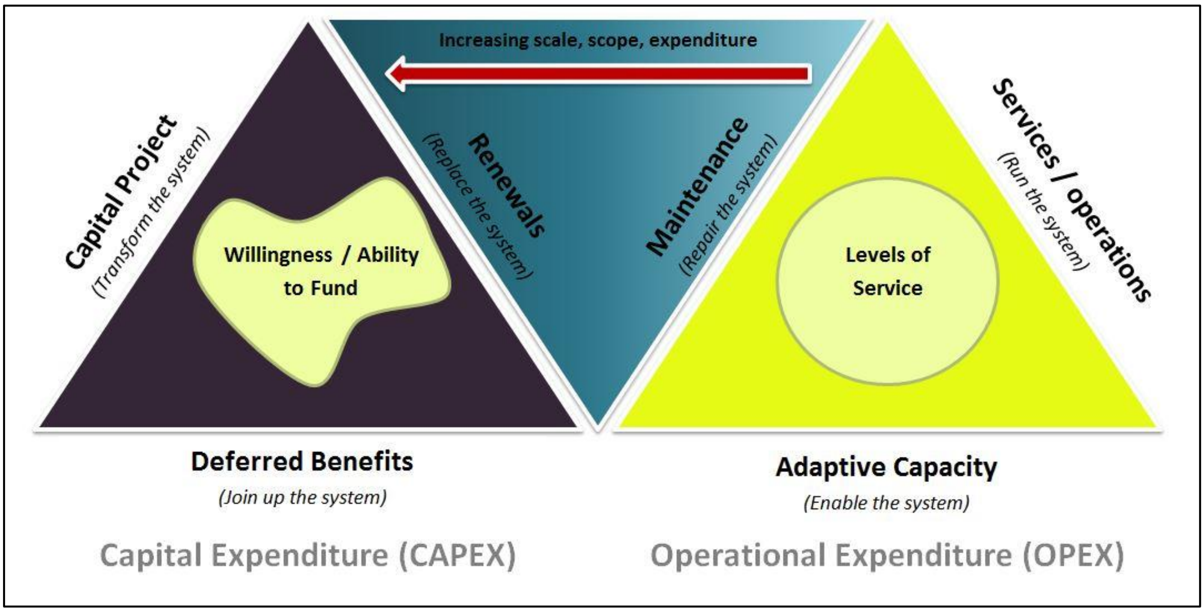

Figure 6: Modified operating model

Tables

Table 1: Summary comparison of consequential OPEX

Estimating method	Estimate (NZ$M)	Comments	% difference to prorated consequential OPEX (*approx.*)
Consequential OPEX			
Actual	Not available	Costs for first year of operations. Actual costs not specifically tracked and not readily identifiable. <1% of the 'total amended consequential OPEX' could be traced.	Not available
Prorated	$2.15M/y	Current estimating method. Assumes OPEX is a percentage of CAPEX. No rate was available for the tunnel and some NZ$167.51M CAPEX had no OPEX in the previous 'estimated consequential OPEX' exercise. To provide a minimum figure, the lesser road rate was applied to the unassessed CAPEX.*	0%
Estimated	$1.26M/y	Recent asset led estimation. This uses rates sourced from Auckland Transport, maintenance contractors, and benchmarks from other similar assets or facilities.	60%
Amended	$2.49M/y ($7.49M/y)	This study. Excluding public transport services, most compliance actions, and tunnel and major structures maintenance costs. Including additional bus services *(which are known within study organisation but not included in previous OPEX estimates)*. Excluding most compliance actions, and tunnel and major structures maintenance costs.	115% (350%)
Additional costs	*$1.06M*	*Additional one off costs able to be readily identified. Includes estimated cost of resolving archaeology, opportunity cost from resale of contaminated land, and emergency and operational training associated with the new tunnel.*	-

** The CAPEX:OPEX ratio arising from the estimated consequential OPEX was comparable to the ratios assumed in the prorated estimate. By contrast the CAPEX:OPEX ratio arising from this exercise was typically greater (sometime significantly so). If relatively minor changes were made to the prorated figures using the lower of the assessed ratios, then the recalculated prorated annual OPEX would be in the order of $3.1M (i.e. +40% of current/prorated and +145% of the estimated consequential OPEX figures). In a study of public transport growth for Auckland, Deloitte (2013) note that the OPEX:CAPEX ratio used in their assessment excludes any consideration of additional public transport services to accommodate growth. That ratio, whilst slightly higher than the rate used in this study for the road related assets, is significantly less than that for the stations.*

Note: The overall accuracy of the amended consequential OPEX cannot be assessed given the scope of outstanding omissions. It is however considered that the amended consequential OPEX is a minimum value. A list of the more substantive omissions and unknowns are given in the body of the text.

Table 2: Summary of wider implications

Issues	Comments
General processes	
Information accessibility	No clear bundle of information aimed at operations. Information archived at end of project delivery including compliance material. Management systems may not assist as data may not be accessible or useable. Difficult to ascertain whether all requirements have been captured and to track changes arising during delivery.
Issue salience and summing of the parts	▪ Project versus operational: 'Best for project' sometimes prioritised over long-term or operational matters (e.g. poor whole-of-life design choices). Compounded by project delivery objectives (delivery cost, programme, construction safety and compliance) do not necessarily align with strategic objectives and system level project purpose. Costs may therefore arise in delivering missing components (CAPEX & OPEX). ▪ Functional focus versus systemic need: Organisational belief systems can lead to assumed boundaries of accountability and belief that excluded matters are either dealt with elsewhere within the organisation or not the responsibility of the functional area. Costs that are not OPEX but still a cost to the organisation (e.g. completing project actions after practical completion) therefore become 'hidden' by being absorbed. Sum of parts does not equal total consequential OPEX / cost to organisation. ▪ Familiar versus less defined: Preference for scheduling assets conventionally found in conventional databases. For example road marking was estimated to the nearest dollar and structures maintenance and renewals were absent. Issue with management tools becoming decision making proxies. Requirements (and therefore costs) were shown to be greater than the sum of the parts; whole-of-organisation assessment required before dividing accountabilities across structure or function.
Compliance	Integration of compliance requirements: Largely omitted from OPEX, raising larger issues of risk and liability, plus potentially significant costs in completing or rectifying mitigation requirements. This also has a potential impact on project benefits as compliance linked to social and environmental outcomes. Compliance also relates to the following matters, which have been integrated in the issues that follow: ▪ The purpose of project documentation: ▪ The completion of project delivery requirements; ▪ Third party interfaces; and ▪ Consequential operational implications.
Strategy and project planning	
Business case and funding	Business case or funding assessments of 'whole-of-life' is not necessarily suitable for calculating consequential OPEX from an operational perspective. Meaning also potentially lost in translation. Does not include maintenance or renewals beyond 40y horizon even though requirements for major structures (for example) may exponentially increase towards the end of their design life. OPEX also not always included in other project scheme assessments (e.g. Maunsell/AECOM, 2007) and attention to operations not part of industry Gateway processes until completion of construction (State Services Commission, 2010, 2013a, 2013b, 2013c, 2013d, 2013e).
Project planning and	Project documentation not focused on operations and often cursory

Issues	Comments
approvals	consideration given in documents. Highlights the need not merely for inclusion of maintenance with design and consenting documents but rather a set of documents to be prepared specifically from the operators' perspective. This would not only facilitate handover but contribute to an improved OPEX assessment early within the project delivery cycle.
Benefit management	Omission of requirements may artificially lower consequential OPEX and erode benefits and / or levels of service. This may not always be obvious as this may manifest at the 'system' rather than asset or project level. Also, the effects of any omission may not be realised within the system that manages it (e.g. externalised effects on society or the environment), and / or the effects are only realised in the long term (e.g. shortened asset life). Consequently OPEX related omissions may not be 'seen' within the infrastructure organisation.
Project delivery	
Design and construction procurement	Operational requirements need to be bolstered within contract documentation and written specially to meet the requirements of the operations teams. This particularly needs to consider how the information is to be accessed and used. Designs need to give more than cursory consideration to maintenance (e.g. robust materials equates to low maintenance), and to specifying exactly which parts of standards and guidelines have been applied. Consideration also needs to be given to organisational capability and capacity, which may also affect budgets ahead of project delivery.
Project completion	Additional organisational costs (may not be OPEX) are omitted and otherwise not directly captured. This includes those costs associated with resolving secondary project consequences (e.g. archaeology), completing mitigation, completing other compliance requirements (e.g. monitoring). Omissions become absorbed or result in consequential spend that was not anticipated.
Deferred benefits	Aligned with benefit management but relates to the reconciliation of statements with project assessments with the finally delivered scope. Examples were often found in relation to claimed improvements to connectivity except that the delivered asset did not connect to a wider network. This raises issues in relation to benefit: cost assessments and the ability to later justify smaller projects to 'join the dots'. This suggests there is some merit in variable project envelopes by mode particularly where walking, cycling, public transport envelopes might logically differ from general traffic.
Operations	
Handover processes	Clear need to improve handover requirements and to ensure full integration of the project into the operational system. Not all requirements had been delivered (especially compliance requirements), or were available meaning not everything could be costed or understood by the operations division. Whilst changes to the handover area would be an obvious first step, limiting improvements to this area is unlikely to achieve an effective change as the issues are complex and interrelated.
Maintenance specifications and requirements	Largely focussed on physical assets, these need to include non-standard (e.g. architectural features, 'blue-green' stormwater management), or consequential impacts (e.g. ongoing contaminated land or archaeological requirements) arising from the project. Consideration as to how variations are managed for non-standard items is also required around precedent, efficiencies, and organisational

Issues	Comments
	capability.
Organisational interfaces	
Organisational integration	See also 'issue salience and summing of parts', above. Significant scope but uncertain cost associated with incremental changes to the 'cost of doing business'. Introduces impacts on transparency, and uncertain accountability. Particularly noted for tasks associated with compliance, social or environmental outcomes, mitigation, risk, adaptation and evolution. Whilst costs may be difficult to define this does not abrogate responsibility.
Third party interfaces	The case study project had a number of operational interfaces with third parties for areas such as rail, dam and stormwater management, parks and landscaping, and traffic control. Because requirements had not been identified and included in a schedule, both costs and transfer requirements had not been fully determined. This included issues with future performance auditing, and follow through.
Programme staging	The implications of delaying future stages on the benefits delivered in Stage 1, the need to undertake deferred maintenance or upgrade 'temporary' project interfaces was unknown. This could add additional OPEX and also CAPEX is auxiliary works are required to adjust interfaces.

Table 3: Change matrix

Change dimensions / *Key issues**	**People**	**Organisational Structure**	**Technology / Technical**
General processes			
Strategy and project planning			
Project delivery			
Operations			
Organisational interfaces			

** Note: Key issues sourced from Table 2. Sub-issues should be identified on an organisation and / or project specific basis, but those identified within Table 2 may provide a useful starting point.*